Performance Analysis of Continuous Flow Intersection in Mixed Traffic Condition

Dr. P. Vedagiri[1],Shikhar Daydar[2]
[1]Assistant Professor, Transportation Systems Engineering, Civil Engineering Department, IIT Bombay, Mumbai 400076,Maharashtra,India, e-mail:- vedagiri@iitb.ac.in
[2]B.Tech Undergraduate Student Civil Engineering Department , IIT Bombay, Mumbai 400076 , Maharashtra , India. shkdaydar7@gmail.com

***Abstract*: The rapid increase in the volume of traffic in most of the countries is surpassing the threshold level of the present transportation system and demands a more efficient and intelligent system to be dealt with. As renovation of urban transport infrastructure is not feasible, there is an urgent need to find alternative solutions to the problem. One way is to devise methods for optimal utilization of available infrastructure (road space) in such a way that the carrying capacity of the roadway is enhanced and the conflict points reduced. This may be achieved by Continuous Flow Intersection (CFI) using pre signal concept which is an innovative traffic signal intersection. The principle behind this intersection is that the main conflicting traffic, i.e. the right-turning traffic is segregated from the main flow at the intersection. This study is concerned with evaluation of Continuous Flow Intersection (CFI) under heterogeneous traffic flow conditions using computer simulation. The analysis of the simulation results show that the CFI design is certainly more efficient when compared to conventional designs even in highly heterogeneous traffic conditions.**

***Keywords*: Heterogeneous traffic Flow, Signalized Intersection, Continuous Flow Intersection (CFI), Microscopic Simulation, Network Performance.**

I. Introduction

The road traffic in Indian cities is growing rapidly and is becoming even more heterogeneous as varied vehicles are introduced in the traffic in the recent past making the available transport infrastructure inadequate and incompetent irrespective of the more civilized traffic in developed countries. As redevelopment ofurban transportinfrastructure is not possible, there is an immediate need to find alternative solutions to the problem. One way is to devise methods for optimal utilization of available infrastructure (road space) in such a way that the carrying capacity of the roadway is enhanced. This may be achieved by the Continuous Flow Intersection (CFI) concept is an innovative traffic signal intersection. The concept of the CFI has been considered since quite recently as an alternative intersection design to traditional at-grade and grade-separated intersections.It enables one or more conflicting movements to take place away from the main intersection at a new crossover intersection, which reduces the number of conflicts at the central node and also increases the capacity without demanding more space.This study is concerned with evaluation of CFI under heterogeneous traffic flow conditions using computer simulation.

II. CONTINUOUS FLOW INTERSECTION (CFI)

Continuous Flow Intersection is an at-grade signalized intersection which can be considered as a sub level between grade separated and at-grade intersections. The principle behind this intersection is that the main conflicting traffic, i.e. the right-turning traffic is segregated from the main traffic flow at the intersection. Instead this traffic is carried to a bay which runs through the opposite traffic. The right-turning traffic is carried through a crossover intersection approximately 180-200 metres upstream of the main intersection i.e. at this pre-signal the right turning vehicles will change their lane and get separated from the major flow . The main advantage of this intersection is that for a CFI (CFI on two approaches), there is a phase reduction resulting in only 2 phases for a 3-Arm intersection increasing the green time for each approach thus enhancing the capacity of the intersection and about the delay we will see in further.

The major advantages of CFI are listed below. As said earlier, there is a one phase reduction for CFI. This traffic signal phase reduction in CFI results in less delay, fewer pollutants and lower fuel consumption than theconventional 3-Arm intersection. The intersection can easily handle more volume and is efficient in terms of land use. Thus it avoids the construction of grade-separated intersections at a later stage. It doesn’t demand not even an extra inch of land to be implemented which is a very positive property of this innovation and it maybe fruitfully used in a space crunched country like India.

III. LITERATURE REVIEW

CFI being a part of some recent research not many have been done regarding it. Jagannathanand Bared.2004studied that although concepts of the continuous flow intersection (CFI) have been around for approximately four decades, minimal or no literature describing these studies. In this paper, the design methodologies for providing pedestrian access and related pedestrian signal timings are discussed. Modeling was conducted on three typical geometries for CFIs with base signal timings optimized for vehicular traffic performance. The results indicate an acceptable pedestrian

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level of service of B or C on the basis of the average delay per stop experienced by any pedestrian for pedestrian crossings at the typical CFI geometries modeled. All pedestrians served at the CFIs are accommodated within two cycles for a typical signal cycle length ranging from 60 to 100 s.Reid and Hummer2001;simulation experiments were conducted using turning movement data from seven existing intersections of varying sizes to compare the travel time of conventional and unconventional designs fairly.

Optimum cycle lengths were used for each design, and a number of factors were held constant to keep the comparisons fair. Off-peak, peak, and peak-plus-15-percent volume levels were examined. The results from the simulations showed that at each intersection one or more unconventional designs had lower total travel times than the conventional design.When considering the design of high-volume intersections like those tested, engineers should seriously consider quadrant roadway intersection and median U-turn designs where rights-of-way are available.YiguangXuan, CarlosDaganzo and Michael Cassidy,2010 studied that a separate turn phase is often used on the approach leg to an intersections with heavy left turns. This wastes capacity on the approach because some of its lanes cannot discharge during its green phases.

The paper shows that the problem can be eliminated by reorganizing traffic on all the lanes upstream of an intersection using a mid-block pre-signal. If drivers behave deterministically, the capacity that can be achieved is the same as if there were no left turns. However, if the reorganization is too drastic, it may be counterintuitive to drivers. This can be remedied by reorganizing traffic on just some of the available lanes. It is shown that such partial reorganization still increases capacity significantly, even if drivers behave randomly and only one lane is reorganized. The paper shows how to optimize the design of a pre-signal system for a generic intersection. It also identifies both, the potential benefits of the proposed system for a broad class of intersections, and the domain of application where the benefits are most significant.P.Vedagiri and KrishnaKumar Subramanian studied that displaced Right-Turn intersection is an at-grade signalized intersection which can be consideredas a sub level between grade separated and at-grade intersections.The right-turning traffic is carried through a crossover intersection approximately 300-400 feet upstream of themain intersection. The main advantage of this intersection is that for a partial DRT (DRT on two approaches), there is a single phasereduction resulting in only 3 phases for a 4-armintersection. A double phase reduction can be achieved using a complete DRT (DRT onall four approaches). This study is concerned with evaluation of Displaced Right-Turn intersection under heterogeneous traffic flowconditions using computer simulation. The model was simulated with a partial DRT and was tested for various traffic flowconditions. The results were compared to the same traffic conditions in the conventional 4-Arm intersection. The analysis of thesimulation results show that the PDRT design is certainly more efficient when compared to conventional designs even in highlyheterogeneous traffic conditions. But this method requires extra space for its implementation which is a major concern in India so needs further improvements.

IV. NEED FOR STUDY AND OBJECTIVE

With the continuous increase in traffic volume it has become a major concern that how to maintain free and convenient flow of traffic. Regarding these issues many researches have been done but considering the Indian traffic none of them is optimum to be implemented on Indian roads due to uncivilized traffic and space unavailability. The goal of this study is concerned with evaluation of Continuous Flow Intersection (CFI) under heterogeneous traffic flow conditions using computer simulation. The study is carried out for different traffic volumes and for different road widths in case the road width is increased in near future.

V. PHASE DIAGRAM FOR CFI (3-ARM INTERSECTION)

In the phase 1 of CFI, the West-bound and East-bound traffic is cleared. Simultaneously the right-turning traffic of the east bound is also cleared from the parallel bay going through the opposite traffic. All the left turns are free as they were in Normal Flow Intersection any phase. During phase 2, the North-bound traffic is cleared along with their right turn traffic. When this happens, the right-turning traffic of the East-bound is allowed to crossover to the bay going through the opposite traffic, and are queued at the main intersection. It may be noted that, a traffic signal at the crossover junction for the through moving traffic in the W-E road is redundant in CFI, and therefore is optional which in this case is absent. But, to improve the efficiency of the intersection and also for safety reasons a signal can be provided. The main purpose will be to avoid the situation where the last vehicles of the through moving traffic might block the green signal for the crossover vehicles, thus reducing the effective green time for these vehicles. Fig 1 & 2 show the phase diagram of the Continuous Flow IntersectionThe East and West bound roads are major roads and North and South bound roads are minor roads.

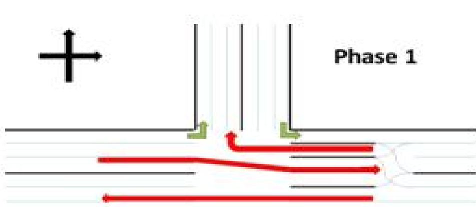

Fig 1. Phase Diagram 1

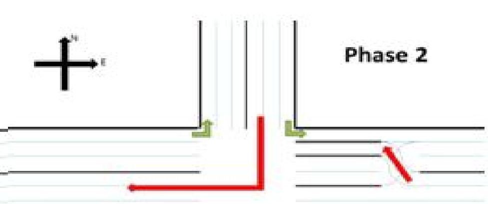

Fig 2. Phase Diagram 2

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VI. STUDY METHODOLOGY

The proposed design was tested using VISSIM simulation software by conducting two experiments. We need to simulate the designs using computer software because it is not possible to practically implement the idea and analyze the results. The simulations thus helps save time and leaves enough for corrections without making a realistic model. First was a comparison between the Normal Flow Intersection(NFI) and Continuous Flow Intersection(CFI) where the major and minor street both were 3 lane roads and in second experiment the major street is a 4 lane road and the minor is a 3 lane road for both 3-Arm Intersections. Fig 3&4 shows screenshots comparing the heterogeneous traffic simulation in NFI and CFI for 3-Arm Intersection.

VISSIM is a microscopic multi-modal traffic flow simulation software .The experiments were conducted for different traffic volumes varying from 500 vehicles per hour to 3500 vehicles per hour for experiment 1 and for 2nd experiment from 500 vehicles per hour to 5000 vehicles per hour for different right turning proportion ranging from10% to 50% of the total traffic volume in one particular approach mainly considering the major street for both 3-ArmIntersections.

The VISSIM software enable usto simulate the design and gives results according to the given parameters. The lane width for every road is 3.5m and the traffic behavior is set according to the heterogeneous and random traffic in India. This enables us to approximate the results to utmost accuracy. It will give us the average delay of all vehicles at the intersection in both the cases NFI & CFI which makes it easier and convenient for comparison. Fig 3&4 shows screenshots of the heterogeneous traffic simulation.

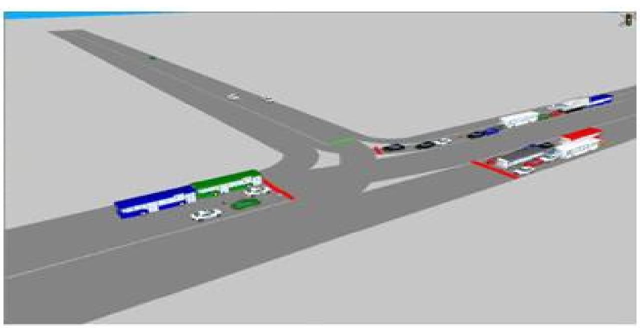

Fig 3. Phase 2 screenshot of the simulation (CFI)

Fig 4. Phase 2 screenshot of the simulation (NFI)

VII. EFFECT OF TRAFFIC VOLUME AT 3-ARM CONTINUOUS FLOW INTERSECTION (CFI).

This experiment is to compare the average delays of the vehicular traffic between the Normal Flow Intersection (NFI) and Continuous Flow Intersection (CFI). Where the major street is a 3 lane road and the minor street is also a 3 lane road. The cycle time for both the intersections is 120 sec. NFI is having 3 phases with 2 sec amber time and green time for phase 1&2 is 50 sec and for phase 3 is 20sec.CFI is having 2 phases with 2 sec amber time and green time for phase 1 is 80 sec and for phase 2 is 40sec. The vehicle composition for both NFI and CFI is same and that is 40% two wheelers, 35% cars, 15% auto, 5% buses, 5% HGV and the traffic behavior is changed according to the Indian traffic conditions. The need to study with different traffic volume is because to understand the behavior of avg delay with change in traffic volumes and even the road width is increased considering that in near future the roads may be widened.Figs 5 to 9 show the graphs for the corresponding data.

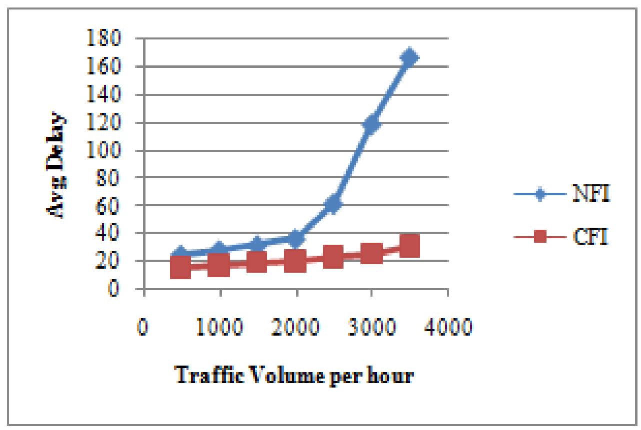

Fig 5. Avg Delay v/s Traffic Volume Graph for “10%” right

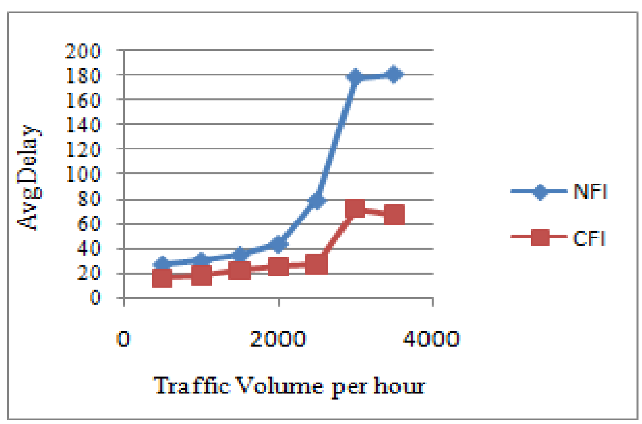

Fig 6. Avg Delay v/s Traffic Volume Graph for “20%” right turning traffic

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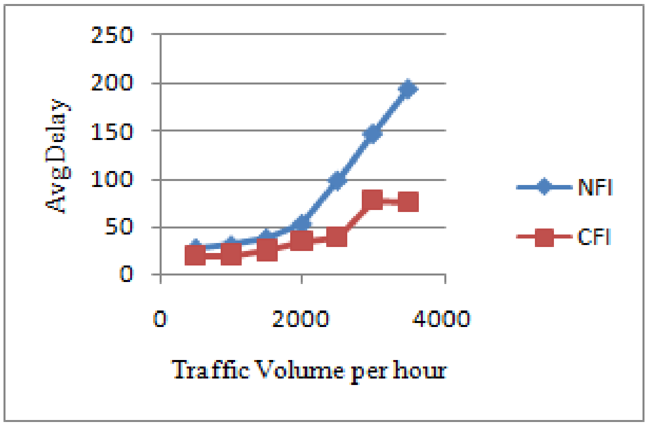

Fig 7. Avg Delay v/s Traffic Volume Graph for "30%" right turning traffic

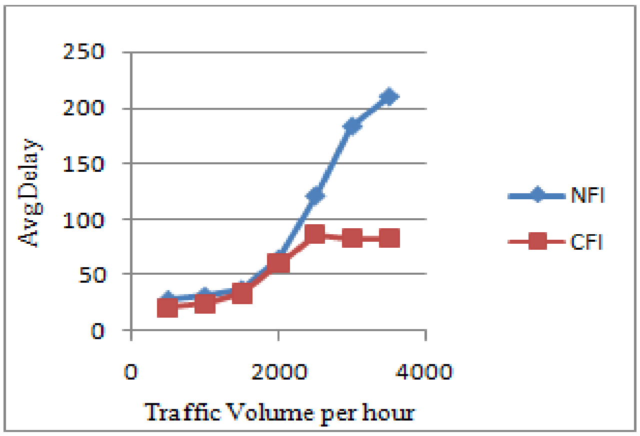

Fig 8. Avg Delay v/s Traffic Volume Graph for "40%" right turning traffic

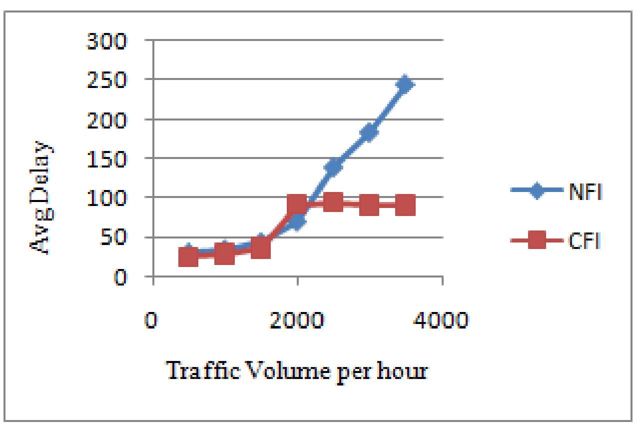

Fig 9. Avg Delay v/s Traffic Volume Graph for "50%" right turning traffic

A. Discussion

The graph clearly shows that the average delay in both the cases i.e. for NFI and CFI increases with increase in the traffic volume though not much difference is not between the graphs when we change the right turning proportions.

The rate of increase of avg delay in NFI is much higher than in CFI but is less than that of a 3-lane intersection but still it proves that CFI is more efficient intersection. In this experiment for all right turning proportions and for all trafficvolumes the average delay is less in CFI than in NFI and the average delay is reduced by 30%-60% in this case.

B. Comments

i) There is no extra field requirement for the implementation of the CFI system; these improvisations can be accommodated in the existing road space.
ii) There are no critical points as such, the avg delay is always less for CFI but for 50% right turning traffic case there are two critical points and it because of some simulation errors in the software as the traffic is not programmed to change lane before turning which causes unnecessary congestion leading to unwanted delay.

VIII. Effect of Traffic Volume and Road Width (4-Lane) at 3-Arm Continuous Flow Intersection (CFI).

This experiment is to compare the average delays of the vehicular traffic between the Normal Flow Intersection (NFI) and Continuous Flow Intersection (CFI). Where the major street is a 4 lane road and the minor street isalso a 3 lane road. The cycle time for both the intersections is 200 sec. NFI is having 3 phases with 2 sec amber time and green time for phase 1&2 is 80 secand for phase 3 is 40 sec . CFI is having 2 phases with 2 sec amber time and green time for phase 1 is 140 sec and for phase 2 is 60 sec. The vehicle composition for both NFI and CFI is same and that is 40% two wheelers, 35% cars, 15% auto, 5% buses, 5% HGV and the traffic behavior is changed according to the Indian trafficconditions. The need to study with different traffic volume is because to understand the behavior of avg delay with change in traffic volumes and even the road width is increased considering that in near future the roads may be widened Fig 10 to fig 14 shows the graphs for the corresponding data.

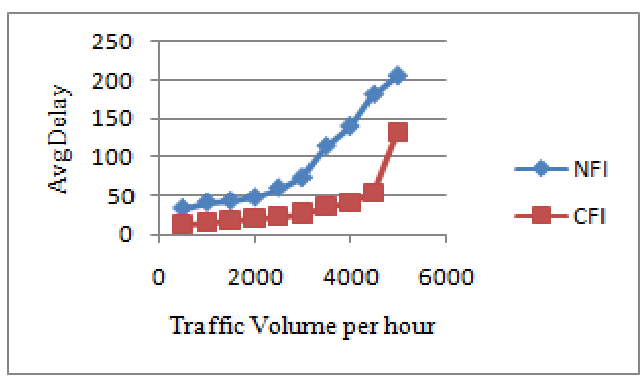

Fig 10. Avg Delay v/s Traffic Volume Graph for "10%" right turning traffic

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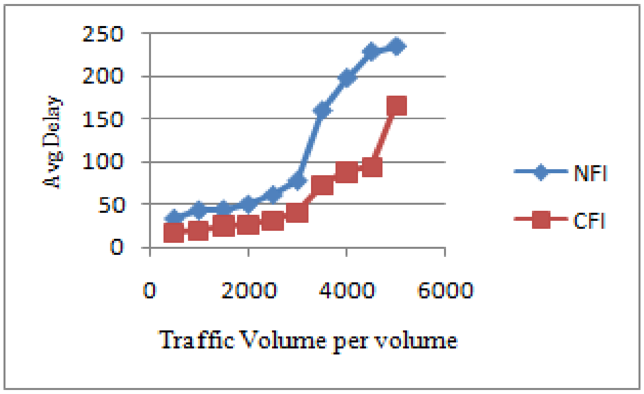

Fig 11. Avg Delay v/s Traffic Volume Graph for "20%" right turning traffic

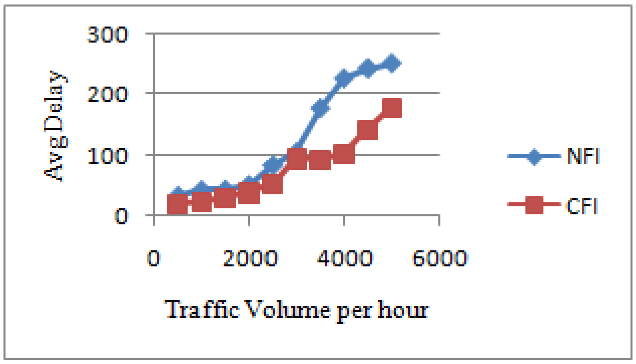

Fig 12. Avg Delay v/s Traffic Volume Graph for "30%" right turning traffic

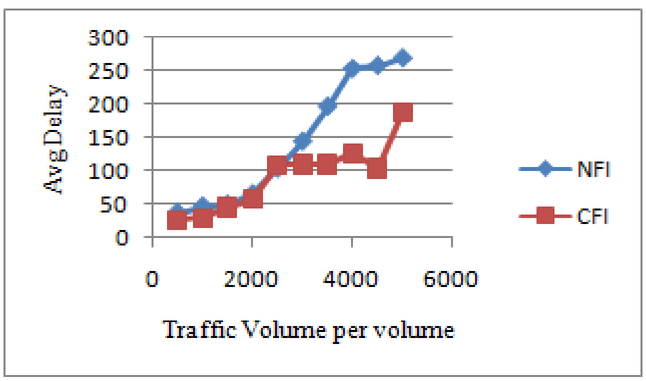

Fig13. Avg Delay v/s Traffic Volume Graph for "40%" right turning traffic

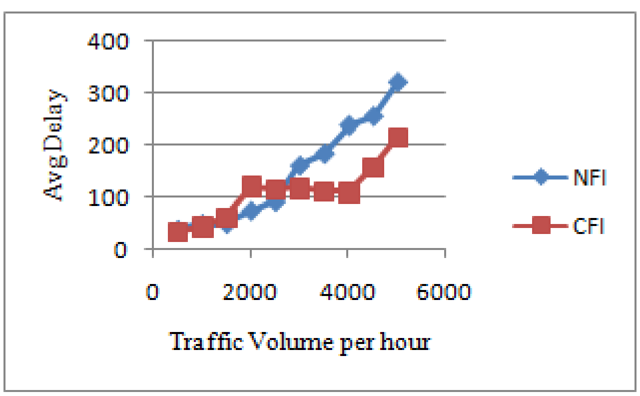

Fig 14. Avg Delay v/s Traffic Volume Graph for "50%" right turning traffic

A. Discussion

The graph clearly shows that the average delay in both the cases i.e. for NFI and CFI increases with increase in the traffic volume though not much difference is not between the graphs when we change the right turning proportions . The rate of increase of avg delay in NFI is much higher than in CFI which clearly proves that CFI is more efficient intersection. In this experiment for all right turning proportions and for all traffic volumes the average delay is less in CFI than in NFIand the average delay is reduced by 30%-50% in this case.

B. Comments

- There is no extra field requirement for the implementation of the CFI system; these improvisations can be accommodated in the existing road space.
- There are no critical points as such , the avg delay is always less for CFI but for 50% & 40%right turning traffic case there are two critical points and it is because of some simulation errors in the software as the traffic is not programmed to change lane before turning which causes unnecessary congestion leading to unwanted delay.

Results and Conclusions

The overall effect of CFI on the intersection is that it was successful in reducing the average delay by a considerable percentage. For traffic volumes 500 &1000 in experiment 1 for both 3-Arm intersections the delay is more but as we increase the traffic volume per hour the average delay is consistently reduced by 30%-50% and for all right turning proportions. For experiment 2 for both 3-Arm intersections the traffic volumes of 500 & 1000 have reduced delays for 10% and 20% right turning traffic and more delay for the rest right turning proportion but as we increase the traffic volume and for all right turning proportions the average delay is consistently decreased by 30% to more than 50%. These are very satisfactory results which are given below for each of theexperiments.

The analysis of the simulation results show that the CFI model is more efficient when compared to NFI model. With increase in capacity for traffic volume, lesser delay at the intersection CFI design avoids the requirement of wider roads and more space. It proves beneficial in every aspect that we tested it in which makes it a satisfactory solution to the problem faced by urban heterogeneous traffic. The traffic assumed included two wheelers, three wheelers, cars, trucks and buses which are similar to the conditions in India. The design can therefore be implemented in each and very areas where there is a need to increase the capacity and reduce delays at the intersection. The study of CFI has proved that the design is efficient in all terms. In the coming years, all signalized intersection can be designed as CFI thereby improving the traffic network efficiency.

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